RoboCupRescue 2006 - Robot League Team
Good Samaritan Urban Search and Rescue Robot (USA)

Luke Abbott, Adam Biegen, Rob Dore, Richard Hopkins, Jude Hueber, Brian Rak, Nate Johnson, Kris Magowan, Noah McKechnie, Ross MacGregor, Dan Schmidt, Jason Komorowski, Jonathan Reynolds

[1] Colorado State University
Department of Mechanical Engineering
1374 Campus Delivery
Fort Collins, CO 80523-1374
clkaiser@engr.colostate.edu
http://www.engr.colostate.edu/me/

Abstract. This paper outlines the functionality and practicality of the Good Samaritan robot. The Good Samaritan robot (GS) has been designed by Colorado State University to provide a competitive platform to be used in unknown and unstable terrain to search for victims. Aspects discussed in this paper are operator station set-up and break-down, robot controlling methods and human to robot interfacing, map generation, victim identification, robot locomotion, innovative mechanical systems, and the cost of the Good Samaritan Robot.

Introduction

The Colorado State University Good Samaritan robotics team is composed of twelve members from two different groups. These two groups are working together to produce a robot called Good Samaritan to compete in the 2006 RoboCupRescue US competition in Atlanta, GA and the 2006 RoboCupRescue International competition in Bremen, Germany. The Good Samaritan Controls group is composed of four real time systems engineering students, one dynamics engineering student, and one electrical engineering student. The focus of this group has been to create a modular control system that allows the Good Samaritan to autonomously navigate the competition arena, create an accurate map of the arena and locate and identify victims with assistance from the operators. The design of this control system allows the robot to function autonomously in the yellow arena and with directed autonomy in more difficult arenas. The system follows the subsumption architecture that Rodney A. Brooks outlines in his book [1] which makes the control system very robust and versatile. A high priority of the controls team has been to make a modular control system that can be moved from one robot to the next with standardized connections. The prototyping and advancements of this team has been performed on the developmental Good Samaritan platform of last year.

The Good Samaritan Platform group is composed of two real time systems engineering students, two composites engineering students, one structures engineering student, and one manufacturing engineering student. Their efforts have been directed towards redesigning last year's platform to be lighter, stronger, modular, robust and more capable while supporting additional sensor and control functionality. Last year's robot was a tracked robot with a parallelogram frame that could modify its shape to traverse different obstacles. The Good Samaritan Platform group has moved away from nylon structural members in favor of carbon fiber composite materials. Several of the improvements include a sophisticated track tensioning system, simplistic and dependable drive linkages and wheel bearings, and ground clearance of the robot. More robust motors and motor controllers have been designed and implemented with improved functionality and performance.

Working in close coordination, the two groups have also designed the robot to accept a well defined sensor package that will allow successful autonomous control of the robot as well as excellent user interaction with the robot. The complete design of this robot is based on sound engineering practices as well as proven and innovative control techniques. The details of the design of this project, which is outlined in the body of this report, affirmatively shows that Colorado State University's Good Samaritan urban search and rescue robot is not only primed for success in competition, but represents a strong foundation for a realistic disaster site robot.

1. Team Members and Their Contributions

- Dr. Wade Troxell — Technical Advisor
- Carl Kaiser — Graduate Project Advisor
- Luke Abbot — Real Time Systems
- Richard Hopkins — Real Time Systems
- Jude Hueber — Real Time Systems
- Jason Komorowski — Real Time Systems
- Kris Magowan — Real Time Systems
- Jonathan Reynolds — Real Time Systems
- Dan Schmidt — Real Time Systems
- Nate Johnson — Composite Materials
- Ross MacGregor — Composite Materials
- Brian Rak — Structures
- Noah McKechnie — Manufacturing
- Adam Biegen — Dynamics
- Rob Dore — Electrical

2. Operator Station Set-up and Break-Down (10 minutes)

The operator setup will consist of one person from the Good Samaritan Team that will be in charge of both station set-up and break-down, along with several alternates in case of emergency circumstances. Detailed checklists have been established and are described below.

2.1 Station Setup Checklist

Laptop Setup

- Connect power cord and turn laptop on
- Connect wireless receiver to unit
- Connect joystick to unit
- Run Good Samaritan control programs

Wireless Communication

- Establish Wireless Communication
- Establish a strong signal
- All units broadcasting

Turn Robot on

Test Systems and Components

- Drive Motors
- Articulation Motors
- Track Tensioning
- Sonar Rangers
- IR Rangers
- LADAR
- Zerolux Camera
- Microphone
- User Interface
- Joystick

2.2 Break-Down Checklist

Robot

- Send termination signal to on-board circuitry

- Make sure Good Samaritan is not moving and in home articulated position
- Turn off power to all on-board circuitry
- Place Good Samaritan in designated container

Laptop
- Close all running programs
- Turn power off
- Disconnect all hardware
- Place laptop into designated container

Additional Components
- Pack up all cables
- Pack up joystick and wireless hardware

3. Communications

The Good Samaritan robot will utilize two different frequencies to control the system. We are employing a 900 MHz radio transmitter/receiver to relay our user input and acquire our map data via the serial RS-232 data format. We will also be transmitting video and audio on a 434 MHz frequency with a mini transmitter.

Table 1. Frequency ranges that will be employed by Good Samaritan during competition

Rescue Robot League		
Good Samaritan (USA)		
Frequency	**Channel/Band**	**Power (mW)**
900 MHz	N/A	100
434 MHz	ATV	100

4. Control Method and Human-Robot Interface

The Good Samaritan (GS) will operate under partial autonomy during missions. It utilizes a subsumptive architecture [1] in which the navigation system will be the bottom layer and will always be functioning. The next layer up is the obstacle avoidance system which can override the navigation processor and take control. Finally, the top layer which can override both of the other systems is the user control layer, which can take over at any point deemed necessary by the user. An overall depiction of this architecture can be seen in Figure 1, at the top of the following page.

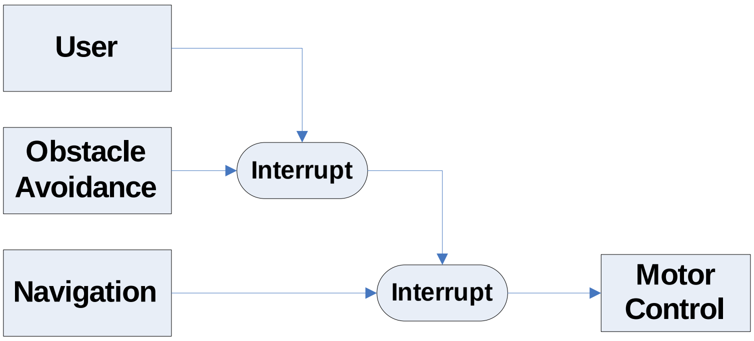

Fig. 1. General subsumptive architecture employed by Good Samaritan

4.1 Navigation Layer

The basic layer of navigation is always running and is completely autonomous as it uses A* probabilistic navigation methods to look for areas of interest. This is a basic exploration process which investigates the environment. It actively analyzes data from the mapping processor which will be described in more detail in Section 5.

4.2 Obstacle Avoidance Layer

The obstacle avoidance layer constantly examines the areas in front of and behind GS to determine the presence of obstacles that the navigation layer may have missed. If GS comes too close (within 30 cm) to something located in front of it, it turns to that object, and determines its traversability based on a set criteria. If it is traversable, it flags the user, and then after a brief pause, it turns away from the object until it is more than 50 cm away from it. This layer is implemented to ensure that GS does not run into any obstacles as it adds a layer of autonomous robustness. It overrides the drive commands that the navigation layer is giving, and uses its own until it perceives itself to be clear of the obstacle. Backwards obstacle detection is used to flag the user that there is something there that may not be traversable in the case that the user is backing up, and does not have the camera turned around to see behind it. It does not take over control at this point, but only lets the user know of the danger.

4.3 User Control Layer

The highest layer that can override the commands from any of the other layers is known as the user control layer. It can be used to intervene whenever the user sees fit, as another layer of robustness. This user control layer also takes advantage of a multitude of sensors which can be employed by the user while the other layers are controlling where GS moves. The user control is made up of a graphical user interface (GUI) created in LabView, which is controlled by a joystick as seen in Figure 2.

Through this joystick, the user can control many aspects of the robot's operation. The user can control drive operations including forward and reverse motion and turning. In addition, the user can manage the degree of articulation. These facets of the Good Samaritan robot are discussed primarily in Sections 8 and 9, respectively. The user can also control the orientation of a Zerolux camera in both the *x* and *y* directions through two servo motors (Figure 3).

Fig 1. The user control joystick. The functions and their corresponding inputs are labeled.

Fig 3. The Zerolux camera is mounted on two servos for multidimensional orientation control.

The user can also switch the view to an infrared camera, and can control the movement and articulation of GS. Both of imaging systems are described further in Section 8. When the user does take control of GS, the drive commands sent by the other two layers are ignored until the moment the user relinquishes control. At this time the navigation layer takes over unless the obstacle avoidance initiates an interrupt as described earlier.

The overall architecture of GS allows the main task of the user to be victim identification. The method by which this is done is described in more detail in Section 7. For the most part, GS can drive autonomously, and therefore the user is free to focus on searching for victims and interpreting the sensor data. The user can take control if the situation arises when a victim is spotted, or when there is an unknown area that needs to be looked at. Therefore the time when the user actually takes control, which is performed by pressing the trigger on the joystick, is only necessary for specific circumstances. This leads to mostly autonomous navigation and obstacle avoidance with the user focused on victim identification.

5. Map generation/printing

The Good Samaritan robot will autonomously generate a map of the environment. It will utilize a dedicated Freescale (Motorola) 68HC12 microcontroller for mapping. This will allow the mapping process to be running continually without being interrupted. An occupancy grid, incremental algorithm will be used for mapping. This algorithm works well in real time and easily allows itself to be modified with Kalman or Bayes filters creating a probabilistic method.

5.1 Mapping Matrix

The occupancy grid that will be used is a two-dimensional binary matrix. This matrix will assume an empty map until cells are filled with a one instead of a zero. The matrix will be sized such that each cell represents a 10cm by 10cm section of the arena. Currently, the map matrix is 160x160 cells. To reduce the size of this map in the microprocessors memory, it will be represented by a series of 20x160 bytes with each byte representing eight binary cells. This gives the map a size of 3.2 kB. This is well under the microprocessor's available ram of 12 kB. When the user requests a map, the processor will send it out serially via the wireless communication cards. At the chosen baud rate, this will take approximately 2.7 seconds to transmit the entire map.

5.2 Mapping Data Mathematics

Mapping will be sensor based using a LADAR ranging device as the primary scanning sensor. This sensor, shown in Figure 6, returns data which is then manipulated to give distance, at a specific angular increment, in meters. This is converted to centimeters in the x and y directions by multiplying by the cosine and sine of the adjusted angle. The adjusted angle is that of the angular increment from horizontal in a counter-clockwise manner, minus the robot's current angular position. These x and y values are then added to the robot's current x and y position, and then stored in the binary map using the following equation.

$$\mathrm{map}[x/8][y]=\mathrm{map}[x/8][y]|(1<<(y\%8))\ . \tag{1}$$

A rendered map matrix is depicted in Figure 4 at the top of the following page. This is followed by Figure 5, which is a photograph of the actual layout. Note that the map matrix has been formatted to add a red background to cells that contain ones.

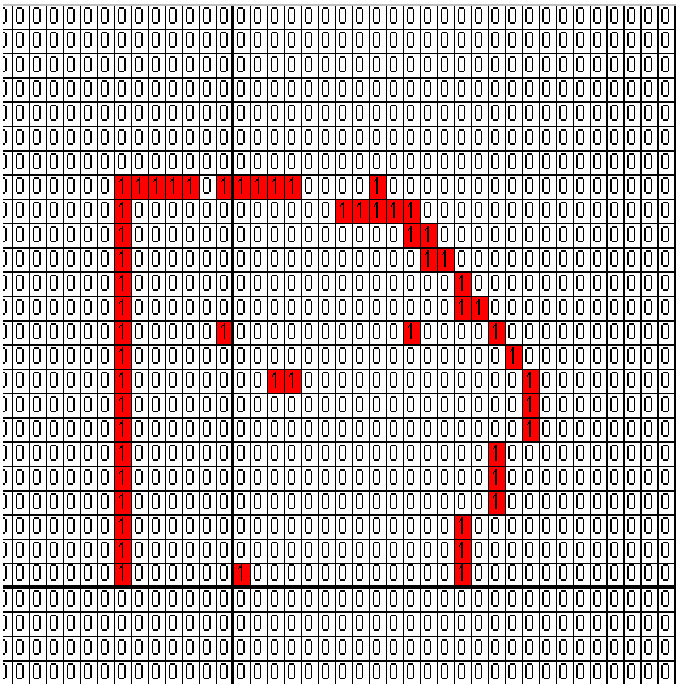

Fig. 4. An example calculated, two-dimensional, binary matrix using the on-board LADAR, indicating Good Samaritan map generation techniques.

Fig. 5 A photograph of the area scanned by the LADAR used to generate the map matrix shown in Figure 4.

Fig. 6. A photograph of the LADAR imaging device.

The robot's current x and y position will be calculated using "dead reckoning" by adding the distance it has moved to the robots previous position. The distance it has moved will be calculated by an Agilent ADNS-2610 optical mouse sensor (now made by Avago Technologies). This package uses a camera with 324 pixels that can detect 64 different levels of light. The ADNS-2610 package will calculate the Δx and Δy distance, since the last time it was read, and send it using synchronous serial communication.

Upon positive victim identification, the user will mark the victim's position by sending the coordinates back to the mapping processor. The processor will then store the data in variables *V1X* and *V1Y* for victim one, x and y position. When the exploration is complete, the user will request the most updated map and can either print it off using a portable printer, or upload the rendered image to a USB flash drive.

6. Sensors for Navigation and Localization

There are many sensors that are implemented to aid in the navigation and localization of the GS. These sensors, specifically the sonar rangers, IR distance sensors, optical position sensor and a digital compass module, are employed by the navigation and obstacle avoidance and user control layers, and by the mapping processor.

6.1 Sonar Rangers

For obstacle avoidance there are several different sensors that obtain data about the surroundings to aid in safe autonomous actions. There are a total of 6 sonar rangers that are situated around the GS chassis. These are shown as the highlighted items in the following figure. One of these sonar rangers is depicted in Figure 8.

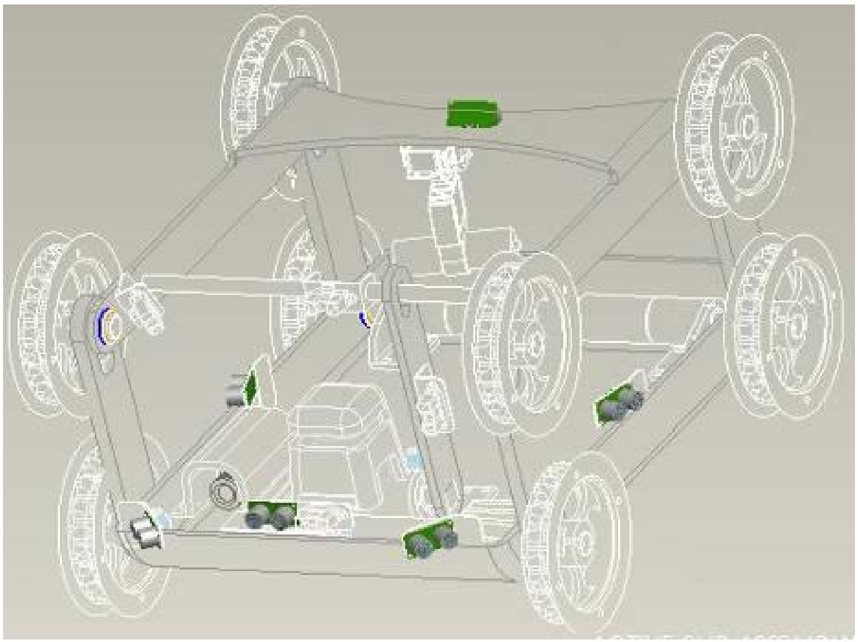

Fig. 7. A Pro/Engineer model of the GS chassis with the sonar rangers highlighted

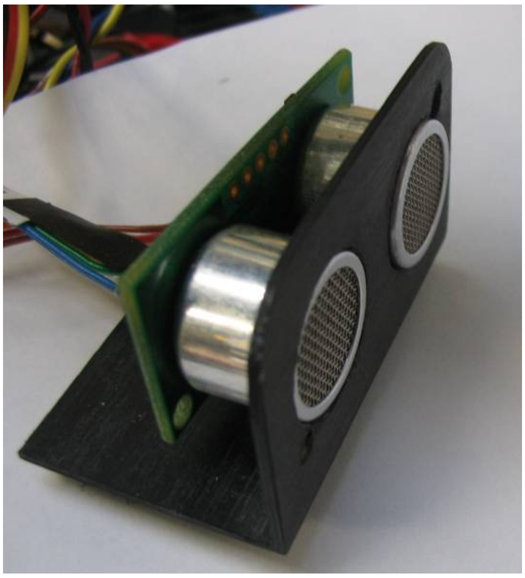

Fig. 8. A photograph of one of the sonar rangers

All sonar rangers being utilized are the SRF05 which have the detection characteristics tabulated below in Table 2. These data were found experimentally, by testing under nominal conditions.

Table 2. Characteristics of the SRF05 sonar rangers utilized by the Good Samaritan team

Characteristic	Value
Max Range	4 meters
Minimum Range	3 centimeters
Initial Angle	30 degrees
Max Width	20 centimeters
Angle of Incidence	> 45 degrees

These are used to add an additional facet of robustness to navigation in situations where the LADAR, which is used primarily for obstacle detection (described in Section 5), does not see an object that is within the defined obstacle boundary. The obstacle avoidance layer will engage when one of the front three sonar rangers detects an object at a distance under 30 cm.

6.2 Infrared Distance Sensors

If an object is detected by a sonar ranger, and it is one of the two diagonally facing sonar rangers mounted on the front, then the GS turns so that it is facing the object, and then looks at the readings of three infrared distance sensors that are located in a vertical array on the front of the GS as shown at the top of the following page in Figure 9. An illustration of one of the IR distance sensors is shown in Figure 10. The IR sensors being used are the GP2Y0A02YK which have been found to have the characteristics shown in Table 3.

Table 3. Characteristics of the GP2Y0A02YK infrared distance sensors utilized by the Good Samaritan team

Characteristic	Value
Max Range	150 centimeters
Minimum Range	20 centimeters
Angle of Incidence	> 10 degrees
Output Angle	< 1 degree to normal

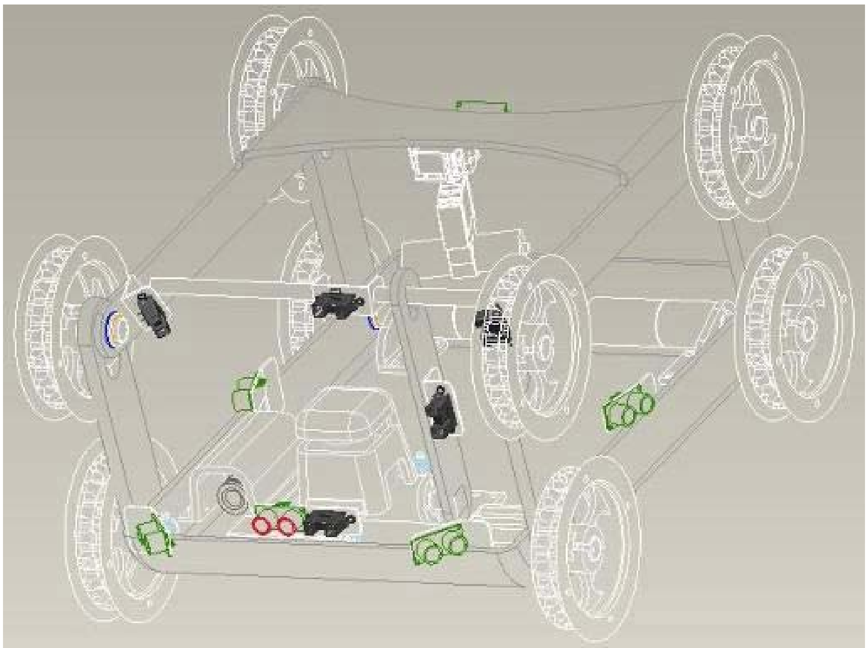

Fig. 9. A Pro/Engineer model of the GS chassis with the infrared distance sensors highlighted

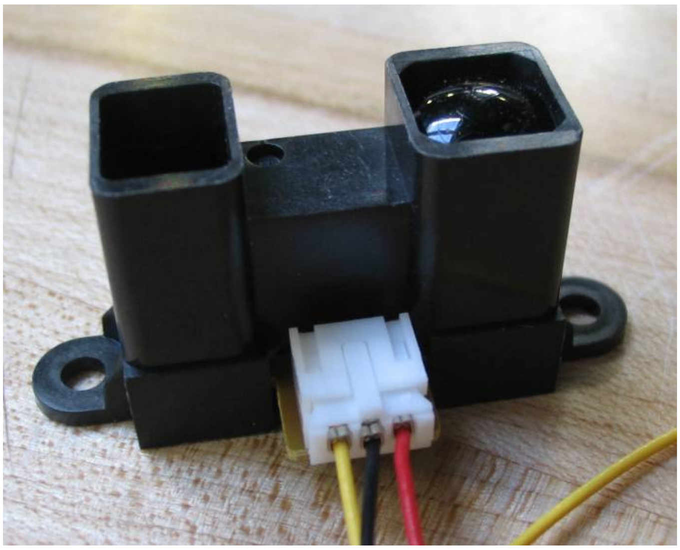

Fig. 10. A photograph of one of the IR distance sensors implemented by Good Samaritan

The infrared distance sensors are used to classify the object that it has come across as something that is traversable such as a ramp or stairs, or an object that is not, and must be avoided, such as a wall. The way in which this determination is made is depicted on the following page in Figure 11. Blue lines indicate detected depths. The illustrations on the right indicate the detection of negative obstacles such as downward ramps, stairs and cliffs.

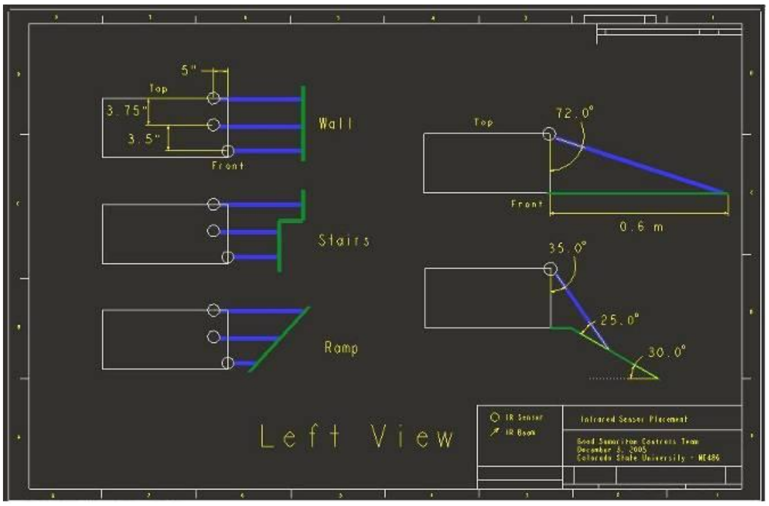

Fig. 11. A Pro/Engineer drawing of the infrared sensors and their determination of different arena objects.

The microprocessor compares the distances of the three IR distance sensors and then makes a navigational decision. If it is traversable, a message is sent to the user through the GUI that displays what type of obstacle it is. It is then that the user can take control and maneuver the obstacle, or the obstacle avoidance layer can be used to control GS around the object. It does this by turning to the left if the obstacle was originally on the right side of it, and to the right if the obstacle was originally on the left side of it. If the obstacle was in the middle, it arbitrarily turns right. It continues to turn until the sonar on the side opposite of the way it is turning senses a distance greater than 50 cm. At this point the obstacle avoidance layer will disable its control interrupt and the navigation layer will resume exploring. A flowchart these navigation operations can be seen in Figure 12 at the top of the next page.

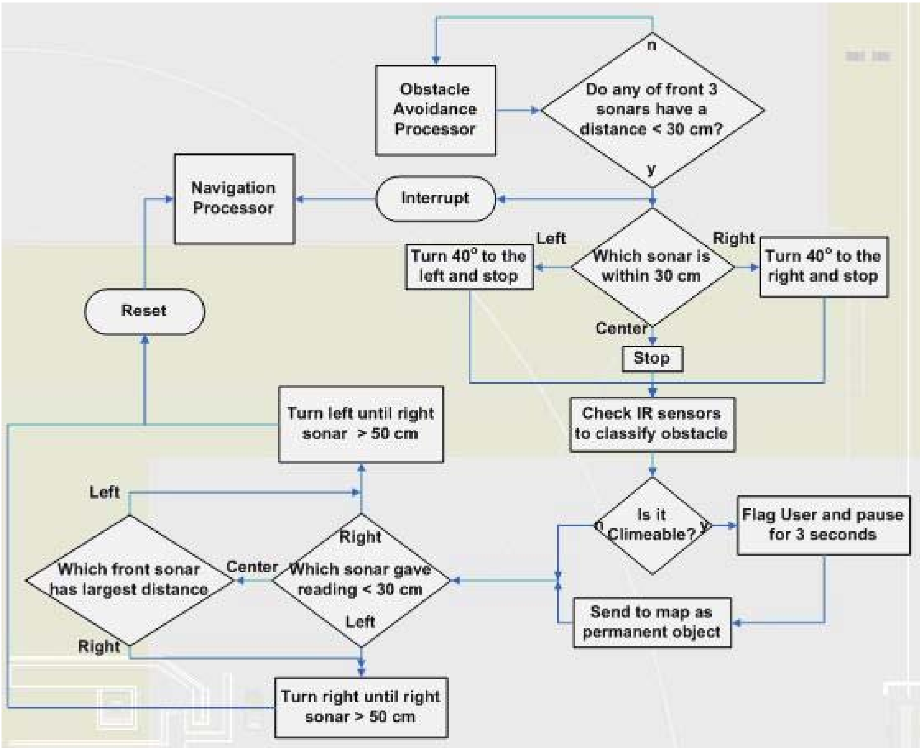

Fig. 12. The navigation decision flowchart for Good Samaritan as performed within the obstacle avoidance layer.

6.3 Position and Orientation

In addition, an ADNS-2610 optical mouse sensor, depicted in Figure 13, will be used for position and localization. This sensor communicates via synchronous serial and will relay the Δx and Δy positions. This will be used as a more reliable alternative to the drive motor velocity and position encoder data, which will be used for alternate purposes described in later sections.

A Vector 2x digital compass module will be utilized for determining the robot's planar angular position. This, essentially, is a dual axis magnometer calibrated using the earth's magnetic field. It has a resolution of two degrees and updates at a rate of 5 Hz. The optical and compass sensors will be used to continuously update the robot's pose (position and orientation) for mapping and navigation purposes. A picture of the compass module is shown on the following page in Figure 14.

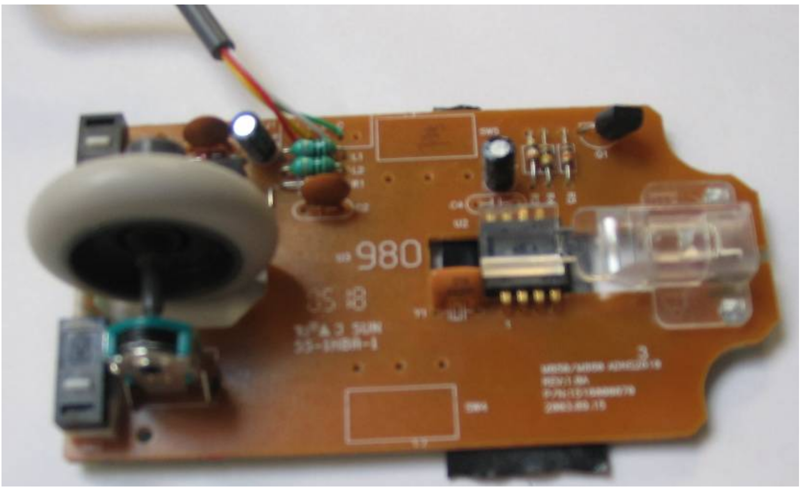

Fig. 13. The ADNS-2610 optical mouse sensor, in its original location mounted on an optical mouse circuit board.

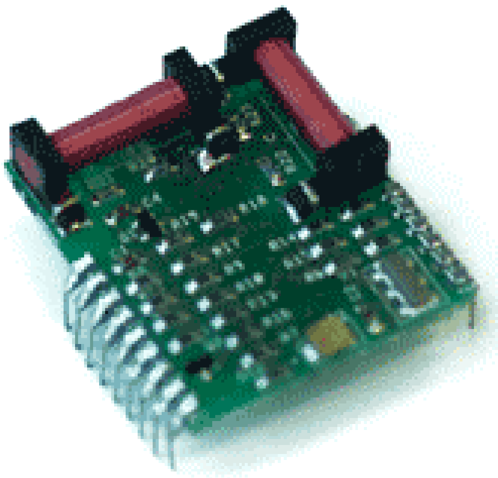

Fig. 14. The Vector 2x digital compass module *(Courtesy PNI Corp.)*

7. Sensors for Victim Identification

For the objectives of victim identification, we will be using sensors that will aide in the detection of form, sound, heat, and motion of the victim. A PC209IR "Zerolux" camera will be used for the user to view the form and motion of the victim, the ThermoVision A10 infrared camera by Flir Systems will be used to detect heat from the victim, and an electret microphone will be used for sound detection.

7.1 Zerolux Camera

The PC209IR “Zerolux” camera will provide the central means for the user to view the surroundings of simulated environment from the perspective of Good Samaritan. The camera will be mounted on a system of two servo motors which will allow the camera to pan-and-tilt, thus controlling the viewing direction of the camera. The movement of the camera will be functional whether or not GS is moving, and the real time image from the camera will be sent back wirelessly to the user’s on-screen GUI via an AVX434 Mini transmitter. An image captured from this camera is shown in Figure 15, below. The actual Zerolux camera and its servo mount are shown in Figure 3 (Section 4).

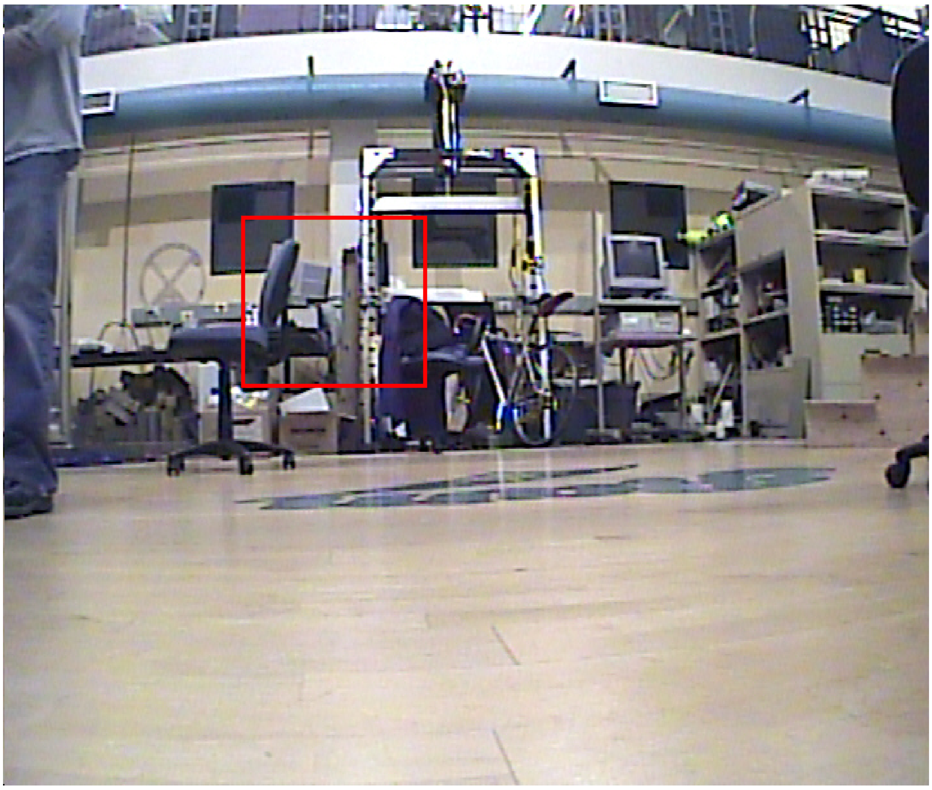

Fig. 15. An image captured from the Zerolux camera. The red box indicates the region viewed by the infrared camera in Figure 9.

7.2 ThermoVision Infrared Camera

The Flir Systems ThermoVision A10 infrared camera will also be displayed within the GUI, and can be used in dark conditions, and is useful for several functions. The user will be able to toggle back and forth between the images captured by the ThermoVision and Zerolux cameras. The infrared camera capable of detecting heat sources from the long distances and is primarily useful for victim location and identification. Also, the infrared camera is equipped with an “isotherm” setting which will allow the easy location of areas within the camera’s view within a user-specified temperature range. An example image recorded with the infrared camera is shown in Figure 16 below. It is using a thermal range of 90°F ± 15°F. A computer is an obvious source of heat, and this is made evident by the thermal image shown. The infrared camera is shown at the top of the following page in Figure 17.

Fig. 16. An image captured from the ThermoVision infrared camera.

Fig. 17. A photograph of the ThermoVision infrared camera employed by Good Samaritan.

7.3 Electret Microphone

The final sensor that will be used for victim identification is an electret microphone. The electret microphone will be mounted on the front of GS and will be capable of detected sounds made by simulated victims. The audio data will be transmitted back to the user via the same wireless transmitter that is used to transmit the video feed. This audio data will be available to the user at all times. An electret microphone is shown below in Figure 18.

Fig. 18. A photograph of an electret microphone *(Courtesy All Electronics Corp.)*

8. Robot Locomotion

The method of locomotion for the Good Samaritan robot is via two rubber tracks, one for each side of the robot, similar to a tank. There are four wheels for each track, mounted in a parallelogram configuration. Three wheels spin freely, while the bottom rear wheel for each side is powered via an electric motor. Each wheel has an XH tooth pattern to mesh with the interior surface of the belt, as shown in Figure 19. The exterior of each belt has 1-inch protruding lugs, roughly 6 cm apart, to aid traction. A picture of the chassis and drive motors is shown on the following page in Figures 20 and 21.

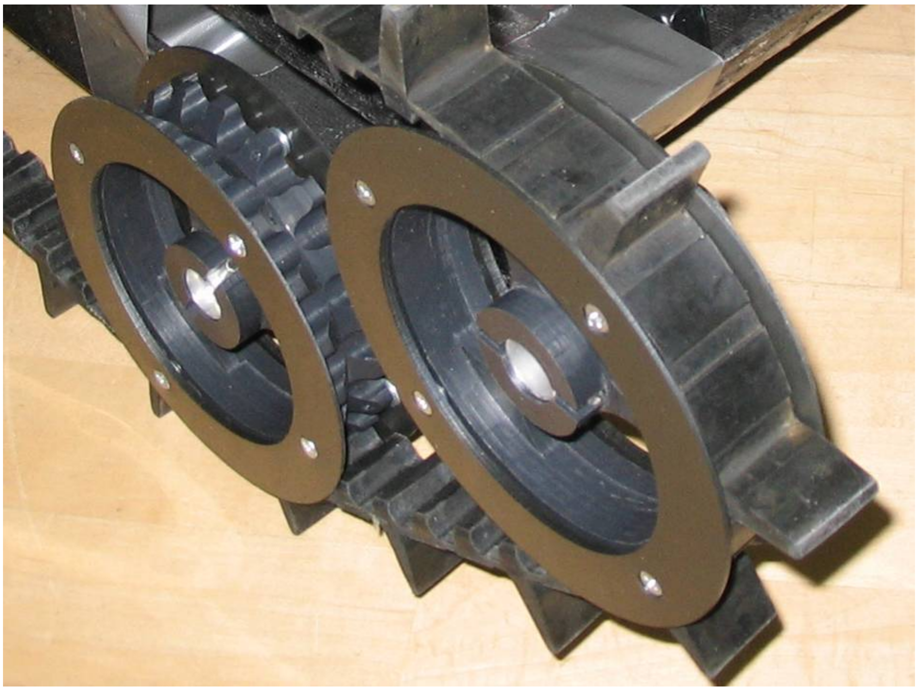

Fig. 19. Good Samaritan Chassis #1: Emphasis on the wheels, tracks and their interface.

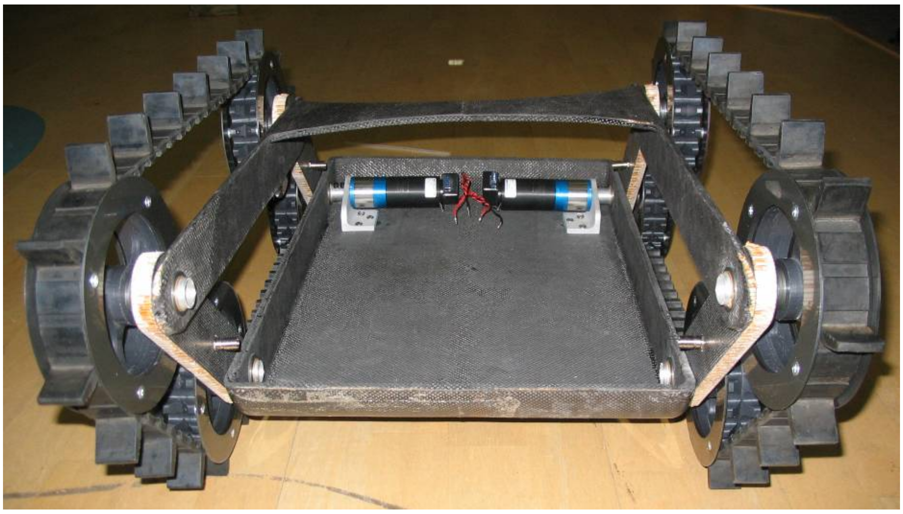

Fig. 20. Good Samaritan Chassis #1: Emphasis on the wheels, tracks and motors with on-board circuitry and sensors removed.

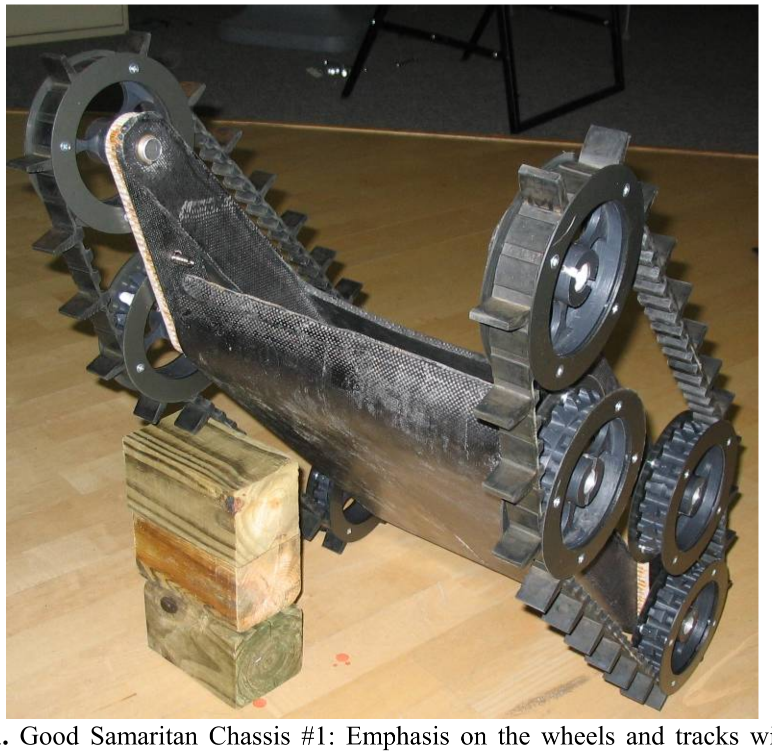

Fig. 21. Good Samaritan Chassis #1: Emphasis on the wheels and tracks with on-board circuitry and sensors removed.

8.1 Faulhaber Drive Motors

The two drive wheels are each driven by a Faulhaber Series 3864 024C motor, pictured below in Figure 22. These are 24V 220W brushed DC motors with a 43:1 gear reduction (Faulhaber 38/2 43:1). They have speeds up to 8000 rpm and a maximum torque of 110 mNm. These motors were sized based on kinetic and kinematic analyses, with additional collaboration with application engineers at various motor companies and vendors.

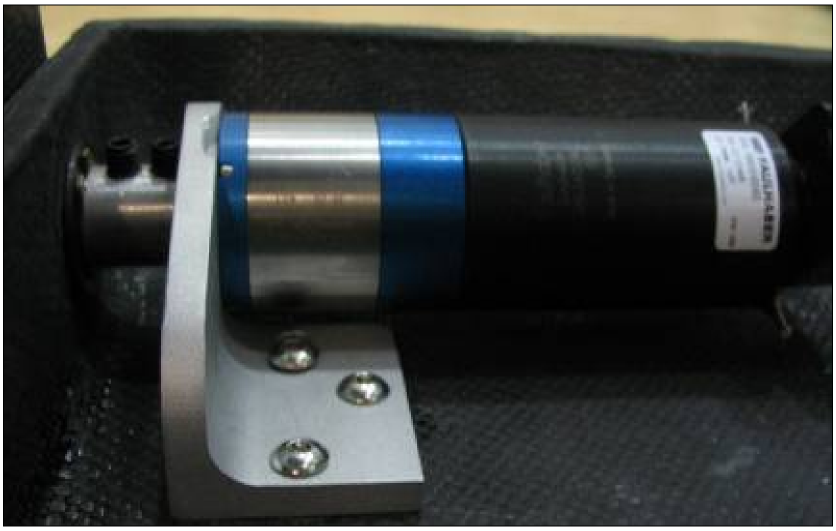

Fig. 22. Good Samaritan Chassis #1: A Faulhaber drive motor is mounted in the chassis of robot. Wiring and circuitry have been removed.

8.2 Open Loop Drive Motor Control

Currently, open loop controllers have been implemented on GS as a temporary means for robot control and environment testing. These controllers use Microchip PIC 16F88 microcontrollers, ILQ174 optoisolators, and National Semiconductor LMD18200T h-bridges. A tethered controller with directional input has been developed. A picture of this provisional setup is shown on the next page in Figure 23.

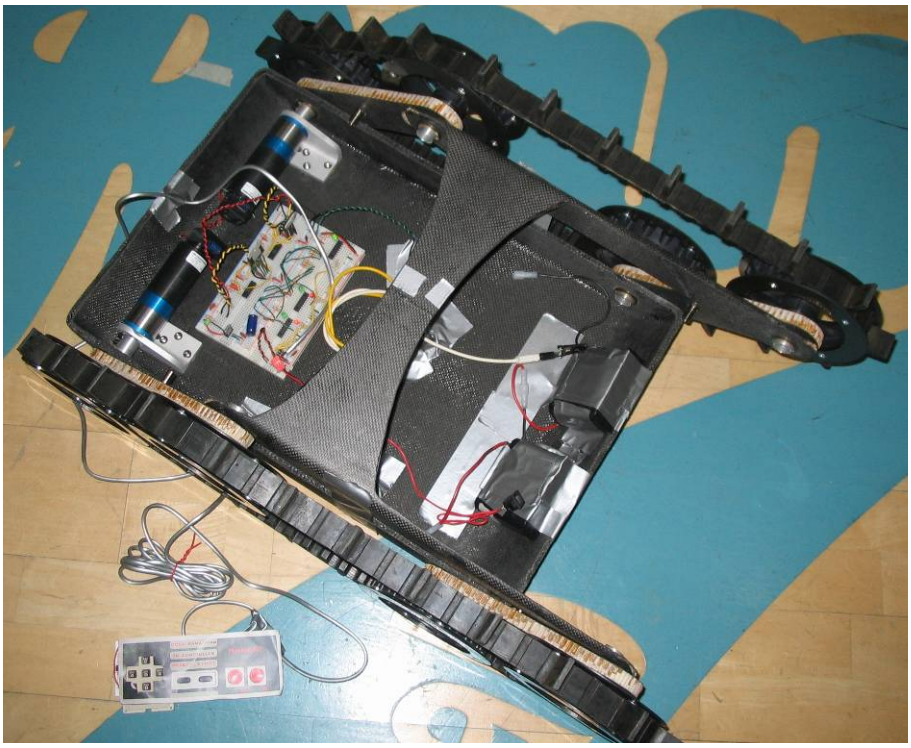

Fig. 23. Good Samaritan Chassis #1: Drive motors and open loop motor controllers are installed with tethered directional control. Note that this is only a temporary setup.

8.3 Closed Loop Drive Motor Control

Motor controllers with closed loop feedback will be implemented for the drive motors. The loop will be closed by utilizing external optical encoders mounted on the drive shaft (Faulhaber HEDS 5500 A). By implementing Microchip PIC 18F2431 microcontrollers, the encoder data is processed in hardware using the on-chip Quadrature Encoder Interface (QEI). This QEI module will record both velocity and position data, which will be referenced and normalized in software for closed loop feedback. A current test circuit is shown on the following page in Figure 24.

These motor controllers are being designed by the team, and will be built using printed circuit boards and surface mount components. IC sockets will be implemented for reprogramming and replacement of microcontrollers and optoisolators. The motor controllers will include several supportive features including velocity and position encoding, variable ramp response, thermal and current protection, multi-mode operation, RS232 serial interfacing, and state-of-the-art optoisolation circuitry (the components were released in January are only available through sampling at this time). This will ensure robustness, durability and circuit protection throughout the competition, and will enable the user and the subsumptive layers to specify the velocity of the vehicle, without direct management thereof.

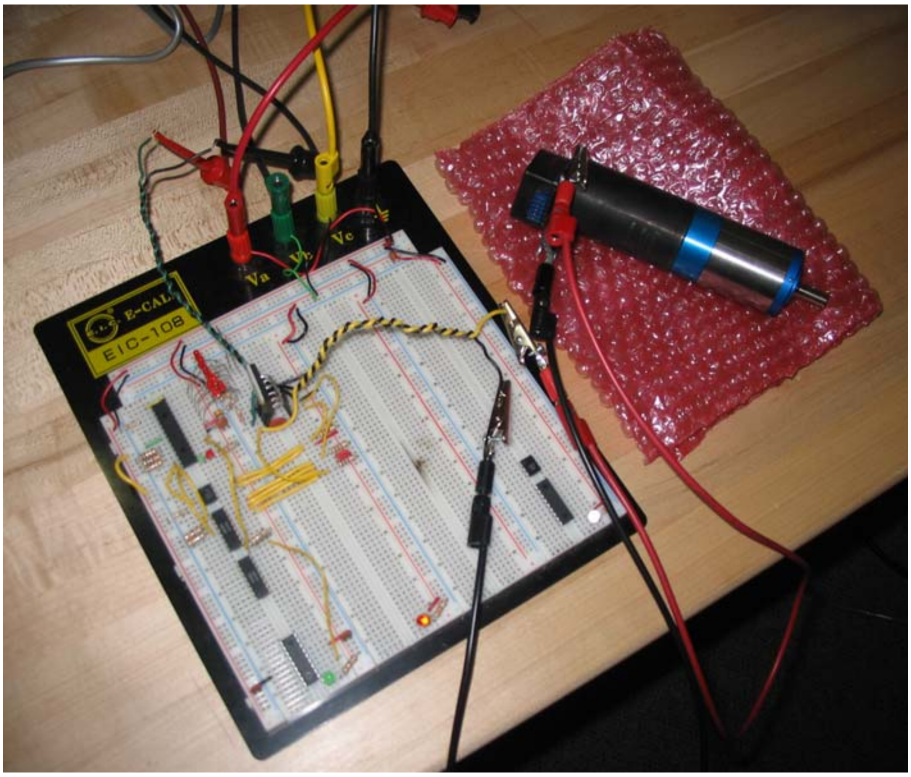

Fig. 24. Closed loop motor controller test circuit with optoisolation

9. Other Mechanisms

The general premise of the Good Samaritan design is an articulating parallelogram, which permits the robot to shift the center of mass either further towards the front or rear, depending on the situation encountered. A carbon fiber composite articulation arm is attached to an electric motor, allowing rotation. The other side of the arm fits around a cylindrical cross-member, which accounts for some vertical motion to permit tensioning of the tracks (described later in this section). When the arm rotates, it shifts the entire parallelogram, causing the location of the center of mass to change, which is helpful when ascending and descending inclines. If necessary, the chassis could also be articulated to decrease its height to permit passage under an overhanging object.

9.1 Articulation Locomotion

The articulation motor is a Faulhaber Series 3864 024C, shown below in Figure 25. These are 24V 220W brushed DC motors with a 592:1 gear reduction (Faulhaber 38/2 592:1). They have speeds up to 8000 rpm and a maximum torque of 110 mNm. Like the drive motors, these motors were also sized based on kinetic and kinematic analyses, with additional collaboration with application engineers at various motor companies.

They will also utilize position and velocity feedback as described in Section 8.3. This will be used such that specific angles of articulation can be specified, and then maintained by the motor controllers. These motor controllers will use the same PCB layout and architecture such that a drive motor microcontroller can be reprogrammed for articulation motor control. Features like ramp response, optoisolation, thermal and current protection will be implemented as with the drive motors. Limit detection and interrupting will also be included such that the range of articulation can be specified so as not to damage vital robotic components.

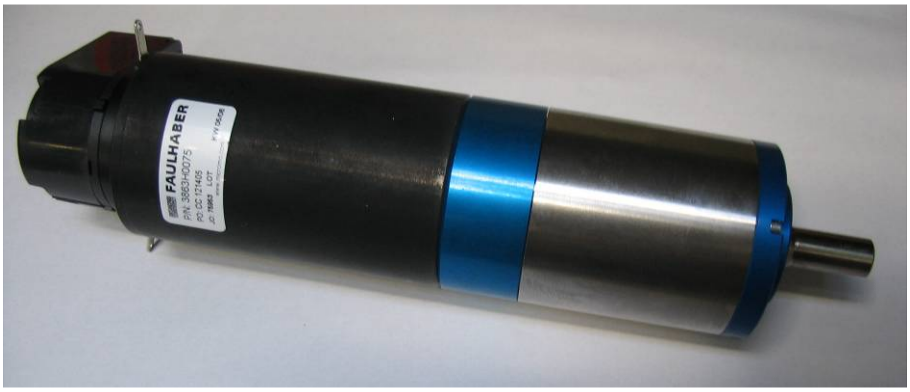

Fig. 25. Faulhaber brushed DC articulation motor with gearhead and optical shaft encoder.

9.2 Pneumatic Track Tensioning

The top two wheels on each side are free to travel vertically, which allows for slack in the tracks for disassembly. To tension the tracks, Bimba Manufacturing Co. (shown independently in Figure 26) pneumatic cylinders are mounted inside of each composite vertical member as seen in Figure 27. When pressurized, the cylinder shaft pushes on a nylon cup that holds the wheel shaft bushings in place. This raises the entire wheel and axle assembly and can be adjusted to different levels of pressure to tension the tracks to specified levels.

Fig. 26. A photograph of a Bimba pneumatic piston, and a corresponding machined cylinder for carbon fiber layup tests. The background is the honeycomb core used in the carbon fiber composites structures that comprise the Good Samaritan chassis.

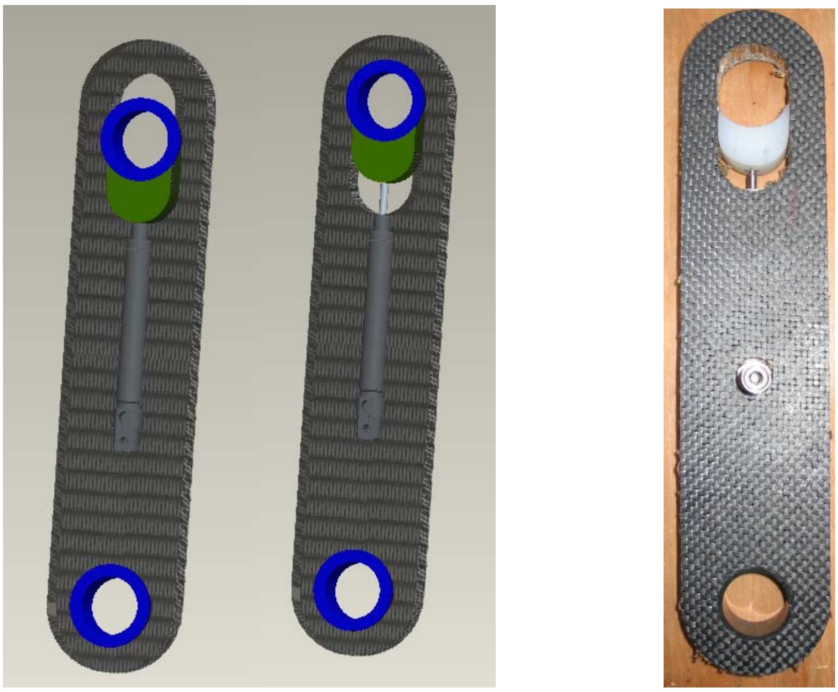

Fig. 27. Actual vertical member with embedded pneumatic piston (left) and a Pro/Engineer model of transparent members to show pneumatic cylinder motion (right).

10. Team Training for Operation (Human Factors)

There will be two levels of operation training. General training will be given to members for testing and data collection purposes, and to increase group awareness. Additional extensive training will be given to select team members who will be potential operators during competition. Maintenance and assembly training will also be conducted.

10.1 General Operation Training

General training for operation of the device will consist of an hour-long training session in which the operator will learn the specific commands of the joystick. This is for Good Samaritan team members who wish to test and analyze robot function. Most, if not all, of the GS team members will receive this training, such that every one is proficient with and cognizant of all aspects of robot operation. This is essential to ensure damage minimization.

10.2 Extensive Operation Training

Extensive operation training will be rigorous and time-intensive, and will be designed to specifically simulate arena and competition environments, as well as introduce potential disaster area elements and problem scenarios. Ambient and distracting noises will be used to condition the user to such potential environments. Lighting conditions will be altered to ensure successful operation in poor conditions.

Problem scenarios will be developed to guarantee that the user is capable of making intelligent decisions with unfavorable circumstances. Scenarios will include power failure, sensor malfunction, device and component repair and communication lapses, as well as other situations to be determined.

This training will be used to asses the candidate's ability to effectively operate the robot, and to decide the most qualified operator for the competition, as well as select and prepare alternates. This will also be a good opportunity to find safeguards and redundancy improvements that can be made to the robot.

10.3 Maintenance and Assembly Training

Additional training efforts will be placed in the maintenance and assembly of the Good Samaritan robots. For modularization purposes, we will have three complete rolling chasses, with a multitude of interchangeable structural and electronic components and sensors. These will be brought to competition to make sure that a fully functional robot is available at all times. It is essential to train and educate team members in the maintenance and assembly of these parts for modularization to be effective. Additional insight will likely be gained from this training, as to find better and more efficient methods of assembly, maintenance, and fabrication.

11. Possibility for Practical Application to Real Disaster Site

While our current platform is still some research and design away from proficient use in competition, its potential is not to be overlooked. At this time, the chassis and onboard motors and controllers are capable of navigating many difficult obstacles such as stairs, fencing and step fields, all while running the motors at less than maximum capacity. The structural integrity of the first chassis is rigid and strong. The sensory capabilities are robust and effective, encompassing the many areas required for effective victim identification. Moreover, the subsumptive layers of control and the user interface are well on their way to successful and practical application in a real disaster environment.

There are areas that suggest improvement may be necessary, but holistically, they do not undermine the effectiveness of the design. Instead, they simply highlight areas where additional elements can be included to upgrade from competition to real world disaster site application. Areas such as self-righting and redundancy in sensor protection are potential areas of improvement that will be made before competition, but might not reach full applicable maturity for disaster site application. Constraints on time and budget have limited research into mass-manufacturability. Overall, this robot provides a very strong candidate not only for competition, but also for eventual disaster site application.

12. System Cost

Below are itemized lists of all purchased components that comprise the Good Samaritan platform. This data represents components procured at this time, and more items will be listed after competition. The first table, Table 4, shows the electronic components used in the design, while Table 5 shows the mechanical components.

Table 4. Data regarding the costs and sources of the electronic and related components for the Good Samaritan platform

Component	Manufacturer	Part Number	Cost	Qty	Total Cost
LADAR[1]	Hokuyo	URG-X003S	$2,700	1	$0
Thermal Camera[1]	ThermoVision	A10	$8,000	1	$0
IR Sensors	Sharp	GP2Y0A02YK	$14	5	$70

[1] Denotes items that have been provided by Colorado State University for competition.

Component	Manufacturer	Part Number	Cost	Qty	Total Cost
Digital Compass	PNI Tech.	Vector 2x	$50	1	$50
Sonar Rangers	Acroname	SRF05	$27	6	$160
Optical Sensor	Avago Tech.	ADNS-2610	$15	1	$15
Zerolux Camera[2]	Super Circuits	PC209IR	$150	1	$0
Pan-Tilt Servo	HiTec	BPT-KT	$20	1	$20
Mini Transmitter[1]	N/A	AVX43MINI	$100	1	$0
Wireless Kit	N/A	E09-009NSC-DK	$210	1	$210
Miscellaneous	N/A	N/A	$300	N/A	$300

Table 5. Data regarding the costs and sources of the mechanical and related components for the Good Samaritan platform

Component	Manufacturer	Part Number	Cost	Qty	Total Cost
Composite Materials[2]	US Composites	N/A	$200	N/A	$200
Nylon Stock[2]	Cast Nylon Inc.	Nylon 6 MoS_2	$181	N/A	$181
Bearings	Igus	MTI-1214-16		8	
	Igus	MFI-1416-12		8	
	Igus	MTI-12	$40	24	$0
Drive Motors: Motors[2]	Faulhaber	3863A024C		4	
Drive Motors: Gear Drives[2]	Faulhaber	38/2S 43:1		4	
Drive Motors: Encoders[2]	Faulhaber	HEDS 5500	$460	4	$1,840
Art. Motors: Motors[3]	Faulhaber	3863A024C		2	
Art. Motors: Gear Drives[2]	Faulhaber	38/2 S592:1		2	
Art. Motors: Encoders[2]	Faulhaber	HEDS 5500	$507	2	$1,014
H-Bridges[4]	National Semi.	LMD18200T	$9	9	$0
Optoisolators[5]	Avago Tech.	ACPL-4800	N/A	9	$0

[2] Denotes items that have been provided by Colorado State University for competition.
[3] Denotes items that have been procured with an academic discount.
[4] Denotes items that have been sampled, or otherwise offered for free by the manufacturer.
[5] Denotes items that are not yet in production, and therefore can only be sampled.

Component	Manufacturer	Part Number	Cost	Qty	Total Cost
Pneumatic Cylinders[3]	Bimba	007-1-XP	$15	16	$0
Batteries: Electronics	Polystor	340948	$4	4	$16
Miscellaneous Items	N/A	N/A	$134	N/A	$134

13. Lessons Learned

After the competition is over, please use this section to add your thoughts on the lessons you learned from deploying your robot and watching others. Your system will change leading up to the event and during the event as you react to changes in your assumptions. This section should capture those changes (although you may also modify all the previous sections as well), and articulate the lessons you took from the experience which will refine your system design.

References

1. Brooks, Rodney. Cambrian Intelligence: The Early History of the New AI. Massachusetts Institute of Technology. 1999.